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Future United States Energy Demand Patterns

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by

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ABSTRACT

The future energy demands of the United States are forecast using a unique approach. The saturation forecasting method reflects the inability of an individual to utilize more than a limited amount of energy. This technique also allows evaluation of various conservation methods and their effects on the future energy needs.

OVERVIEW OF ENERGY USE AND DEMAND

We in the United States use extremely large quantities of energy each year; in 1970 a total of 67.8 quadrillion (67.8Q) BTU were used. An idea of how much energy this represents may be obtained by comparing the energy needed to boil a certain quantity of water. One Q of energy is necessary to boil away the amount of water in an area of one square mile covered with 515 feet of water.

The present method of obtaining most of the energy is the burning of various fossil fuels: coal, natural gas, and liquid hydrocarbons. These fuels are available in some limited quantity and their formation rates are much less than present usage rates. As the supply of these traditional fuels decreases, their value, as both a fuel and a raw material, increases. Thus, these sources must be consumed at a decreased rate or alternate energy forms must be discovered.

In this paper, emphasis has been placed on minimizing the use of energy, while meeting reasonable demands of our society. Due to the many and complex uses of energy, a careful study is made of the several different areas of the entire energy picture. The demand for energy involves a study of the forms of work and a forecast of the quantities required for each form.

Considerable historical data is available concerning energy usage; additionally, other studies indicate the amounts of available supplies and their condition. Future energy demands have been predicted in several studies [1 through 17]. Methods used in these projections have various bases, some being: population growth, trending of historical data, gross national product, regression techniques, energy use per capita, and questionnaires, opinions, and judgement.

The growth of demand energy has been based on the increased production capacity of the United States. To maintain its place in the world, this country has developed many new processes to produce conveniences for its people not thought to be necessary by earlier citizens. As a result, energy demand has grown very rapidly as shown by the doubling times for energy use in Table I.

TABLE I. DOUBLING TIMES FOR ENERGY USE

Year	Annual Use (10^{15} Btu)	Doubling Time (Years)
1910	17.0	--
1948	34.0	38
1970	68.0	22
2000(est)	136.0	30

Many of the resulting projections of demand follow a historically established exponential curve into the future. This method is popular not only in demand forecasting, but has been used in other areas where exponential growth is historically true. An example is the study performed by a research group at MIT, the results of which are published in the book "The Limits to Growth" [18]. However, this analysis for future demands for energy does not support the exponential growth projection. The forecasting of demand in this paper does not follow any of the previously mentioned methods per se, rather it utilizes a method of <u>saturation forecasting</u> applicable to most areas of energy use.

The saturation concept reflects the inability of an individual person or household to utilize more than a certain amount of energy due to time and spatial constraints. The time restraint implies that each person has within each day a number of activities, each having the use of energy connected with it. Although this individual has the option to select among the activities, only a few may be engaged in at one time. Each individual has a limited amount of space, which is necessary and sufficient for a selected activity. Thus, an individual can engage in an activity only as limited by space and time, only a limited amount of energy can be expended. By forecasting the time and space required for activities, maximum energy usage per capita (saturation) may be established.

Conservation efforts are detailed to obtain what are reasonable appearing projections when factors of environment, scarcity of energy sources, and costs are considered.

The total energy demand forecasts were obtained by the 'building block' or composition forecasting method. This required the forecasting of saturation and conservation demand for the different individual use areas. The projections were then combined to obtain forecasts of the common user areas, these being:

residential and commercial
industrial - fuel
transportation
electric power generation
industrial - chemical

The complexity of the U. S. energy use patterns of **1970 is depicted in Figure** 1 [14]. The future demand **pictures for total energy** are presented in Figure 2 **(saturation) and Figure** 3 (conservation). Details of **the logic behind** these curves are given in the ensuing **sections.**

FUTURE DEMANDS

Residential and Commercial

The residential uses of energy are concentrated in houses, mobile homes and apartments. In 1970, there were 64.8 million households in the U. S. This is expected to increase to 90 million (39% increase) by the year 2000. The commercial area encompasses energy requirements of the facilities utilized by business, but not for the production of producer of consumer goods. Typical facilities are retail, whole-

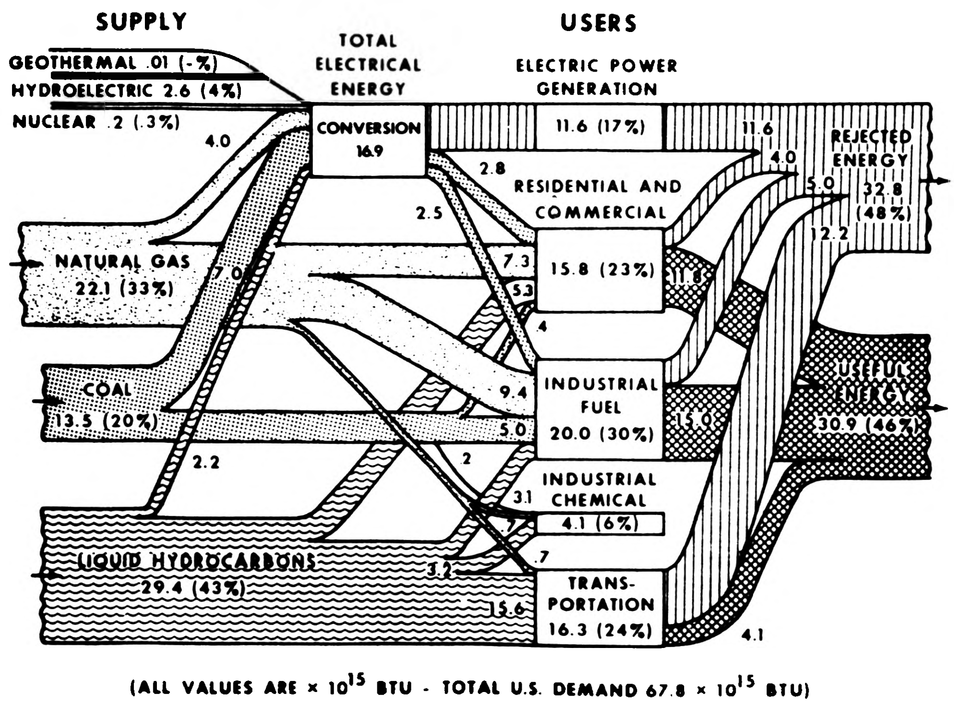

Figure 1. U. S. Energy Demand Patterns, 1970

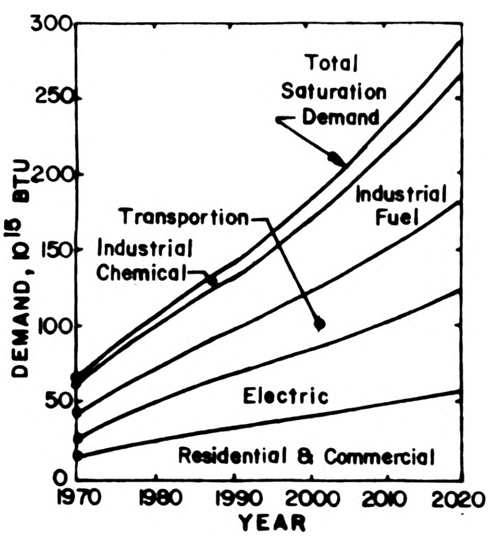

Figure 2.
Total Saturation Demand by Area, 1970-2020

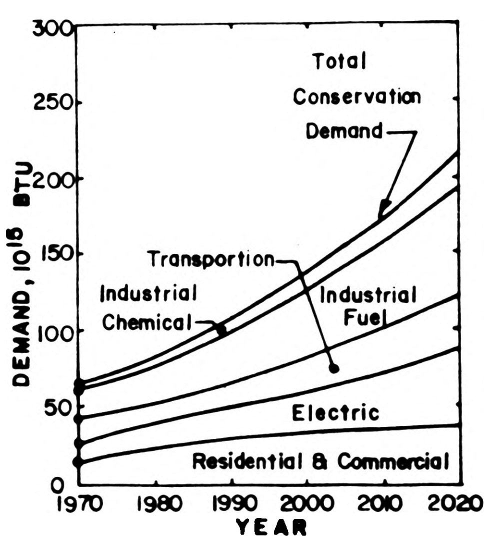

Figure 3.
Total Conservation Demand by Area, 1970-2020

sale and sales organizations, hotels, and office space occupied by service and industrial groups.

Eighty-eight percent of the total residential and 77% of total commercial energy is expended on space conditioning (heating and air conditioning), water heating, cooking, and refrigeration [15]. Residential energy needs are supplied by electricity (15%) and fossil fuels (85%). Commercial, representing approximately 15% of total area energy demand, derives 65% of its energy from fossil fuels and 35% from electricity. The last decade has seen particularly large increases in air conditioning and other comfort items. Historical consumption growth rates have been 2.7% for residential and 3.7% for commercial [4].

A summary of the 1970 household energy consumption and device ownership is shown in Table II. This table also provides the starting point to define saturation in this area. As facilities necessary to provide comfortable surroundings of adequate space are completely installed in a home, some limit is reached. This limit interpreted as a saturation demand for the individual household, was obtained by assuming that each household was adequately heated, completely air conditioned, and supplied with heated water, refrigeration, adequate lighting, and a number of convenience appliances. This will place each household at a demand of about 400 million BTU's annually.

TABLE II. PATTERNS OF 1970 HOUSEHOLD APPLIANCE OWNERSHIP AND ENERGY USAGE

Household Item	No. of Households with Item (millions of Households)	Percent of Households	Energy Use (million BTU per Household Year)
Space Heating	64.8	100.0	110.0
Air Conditioning (Room)	26.0	40.6	
Air Conditioning (Central)	8.9	13.7	7.0
Water Heating	35.7	80.5	28.5
Cooking	64.8	100.0	10.5
Clothes Dryer	34.7	53.5	3.4
Refrigeration	63.9	100.0	11.4
Other			20.4
Total			191.2

Commercial uses of energy do not fit an exact definition of saturation but the growth in this area is affected by the population growth and the proliferation of the services provided to the public. These two factors will cause growth in the commercial area of about 3.5% annually until population growth is reduced. Figure 4 represents the saturation demand for both residential and commercial areas.

Conservation will be seen in this area due to shortages and pricing changes of fuel. The conservation curve of Figure 4 reflects major conservation in both residential and commercial by the use of better insulation and design techniques which can reduce the thermal losses of a structure by 50% [15]. This will eventually produce a 25% savings of energy in residential and 30% in commercial. Unfortunately, full effect of this is long term since its application is only to new construction.

Besides the above, a 6% savings of the anticipated 1985 household load of 400 million BTU per year will be due to increased device efficiency in lighting, water heaters, ranges, refrigeration, and air conditioners.

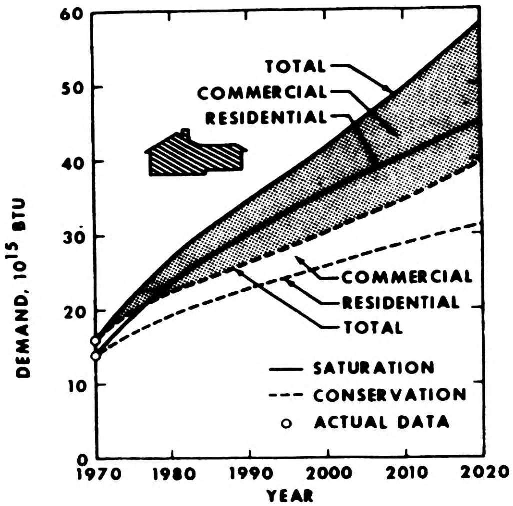

Figure 4.
Residential and Commercial Demand, 1970-2020

Transportation

The transportation area encompasses the energy in all fuels consumed to provide motive power for passenger and freight movement. This area, the most visible of all energy users, consumes 24% of total energy. A variety of modes, all fossil fuel based, are prevalent, but all may be compressed into four general groups. These are private automobile travel, 55%; freight carrier, 27%, including highway, rail and water systems; commercial passenger, 8%; other, 10%, including off road uses and pleasure crafts. Each is given with its share of energy consumption.

The 4.1% yearly growth rate [19] of the recent past has occurred primarily due to increases in truck, automobile, and aircraft traffic. This, of course, is readily seen from the proliferation of highway and airport construction, which encourages a decentralized style of living, working and recreation. The demand for transportation energy will continue to grow, but a decline in the growth rate is anticipated. Saturation demand is defined by a limit in private automobile travel. Presently automotive travel represents a considerable amount of time in each person's day (approximately one hour). However, there is some reasonable limit on the time available for travel when other personal activities are accounted for. The movement of freight and commercial passenger travel are expected to grow at a rate paralleling industrial growth of 3% per year. Projected demand for transportation with the above saturations is pictured in Figure 5.

Conservation efforts to reduce total miles traveled can reasonably be expected to occur in the transportation area as the energy shortage and rising fuel costs become more dominant factors. A total of 35% of the private automobile travel is work oriented [15]. An immediately available conservation effort is the use of car pools for this travel, which can affect about 20% of the transportation energy use and could result in a 10% savings. A more realistic view of work oriented traffic would expect 30% of the travel by one person in a car, 40% in multiple occupancy autos and

40% by some form of mass transit. This would cause an 11% fuel savings by 1990. Again, a change in the private automobile, which can be anticipated by 1985, is extensive use of the more economically sized vehicle. These effects on fuel consumption would amount to a 33% savings for auto use. Nearly two-thirds of car use is independent of employment travel, these activities include family business, entertainment, visits, and vacations. As economic pressure is exerted, anticipated changes include both declined use and a shift to less energy intensive modes of travel.

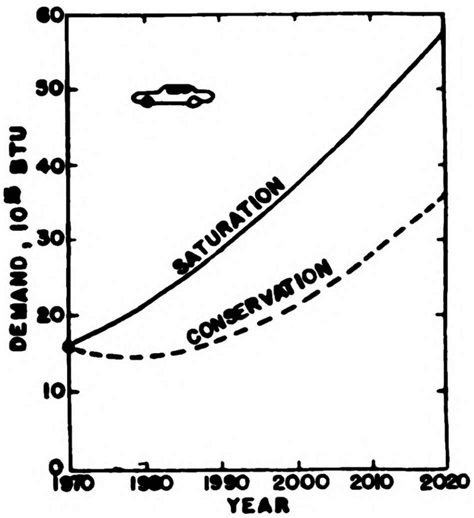

Figure 5.
Transportation Demand, 1970-2020

Table III shows some of the expected changes in the patterns of use for various purposes. Commercial freight traffic consumes a sizeable portion of the energy used in transportation (27%). As fuel costs rise and highway traffic increases, some shift in the mode of freight shipment is anticipated. Shifts to modes requiring less energy as well as reduction of multiple trip shipment of the same material is anticipated to reduce the truck energy consumption by 50%. The cumulative effect of these conservation efforts on transportation energy use is shown in Figure 5.

TABLE III. PRESENT AND EXPECTED NON-WORK ORIENTED AUTOMOBILE TRAVEL

Travel Purpose	1970 Mileage (%)	1980 Savings (%)	Transfer to Commercial (%)
Family Business	24.6	15.0	4.0
Entertainment	18.6	10.0	2.0
Visiting	12.2	10.0	3.0
Business Related	8.0	6.0	---
Vacation	2.5	1.5	0.5

Industrial-Fuel

The consumption of energy in the processing of materials is currently the largest single area of energy use (30%); including the use of electrical power and fossil fuels. Some of the principal sectors of industrial-fuel use are (percentage in parenthesis represents its 1968 share of area energy use)[19]: primary metal industry (21%); chemicals and associated products (20%); and petroleum refining and related industrial (11%). The energy demands of the industrial-fuel area are supplied by a variety of fuel sources; natural gas (47%), coal (25%), liquid hydrocarbons (16%), and electricity (12%). Historically all sectors have shown a decrease in the energy used per unit output. This trend has been altered recently due to environmental restrictions and the greater effort needed to obtain raw materials as supplies become increasingly scarce and more remote. The past increases in efficiency (due to new processes, automation and recycling), largely responsible for decreases in energy per unit output [14] are expected to return to overtake the present short term trend of increased energy per unit output. Growth in industrial-fuel has been 3% per year in the past and is expected to continue at this rate for future demand, thus displaying no real saturation, however, saturation has an effect due to the personal traits of the consumer. This continuation is anticipated due to the need for new products, population growth and necessary replacement of presently owned goods. The projected demand is shown in Figure 6.

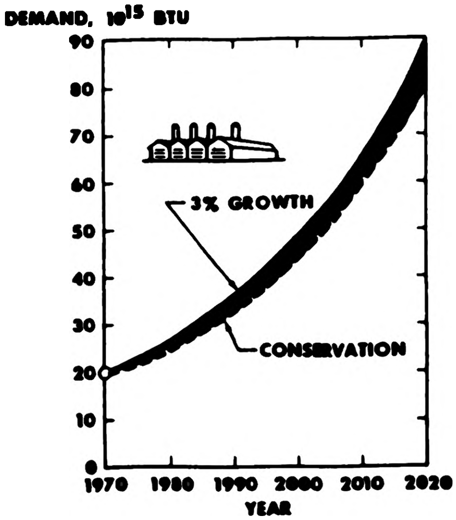

Figure 6.
Industrial-Fuel Demand, 1970-2020

Future conservation is anticipated in this area as energy economics are changed. The most likely areas are: more efficient equipment and processes; better maintenance policies; replacement of old equipment; and more conscious use of energy.

These measures could save as much as 20% of energy used as industrial-fuel, if very severe economic pressure were present. But, it is most likely to only produce a 10% savings.

Industrial-Chemical

The industrial-chemical area has no true demand for energy, but uses fossil type materials as raw materials in the production of goods. Thus the demand curve will represent the equivalent energy contained in these end products, some examples being: ammonia, plastics and resin materials, synthetic rubber, lubricating oils, and a diversity of other products.

Growth in the industrial-chemical area has been 6% per year in the recent past. This rapid growth has resulted from the many new products derived from fossil materials and a growing demand for these products. The demand for products derived from the traditional fuels used as raw materials can be expected to increase as the use of fertilizers and convenience consumer goods increases. The anticipated growth rate, however, will decrease from the present 6% per year to 3% in 1985 due to limits in the amount of these goods which can be beneficially utilized. The saturation curve of Figure 7 reflects this decreasing growth. A more conservative projection results when consideration is made of a fossil material shortage and the effects of these synthetic products on the environment. Under these conditions the growth rate is expected to decrease to 2.5%.

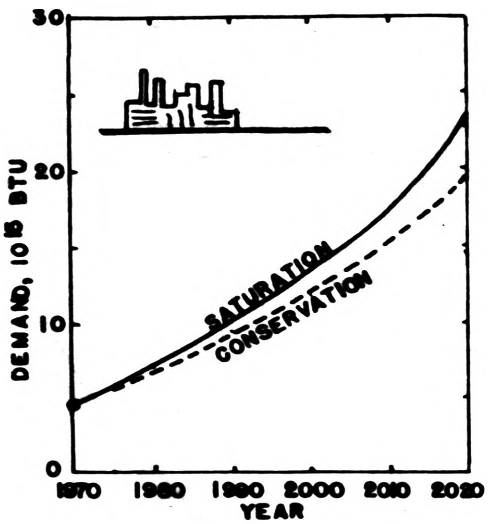

Figure 7.
Industrial-Chemical Demand, 1970-2020

Electric Power Generation

In as much as the useful output of the electric generation industry has already been accounted for in other use areas, this area is defined as the energy which shows up as rejected heat from total energy for electric generation and distribution. This is approximately 69% of the input energy for generation and distribution.

Electric power generating energy is obtained from various sources: coal (46.5%), natural gas (23.5%), hydropower (15%), liquid hydrocarbons (13%), nuclear and other (2%). Environmental and scarcity factors are a pressing reminder that other forms of fuel must in the future represent a much larger portion of the energy sources.

The demand for electrical energy in the user area has grown rapidly in the past (7% per year) due to the convenience and active promotion of this form of energy. Since the user determines the energy need in electrical power generation, the respective area demands define the future needs for this area. Of the present residential energy, 16% is supplied by electricity. This is expected to increase to 30% by 1985 and to 35% by 2020, due to the increasing use of electrical devices in the residential area. The commercial area use of electricity is anticipated to grow at the commercial growth rate of 3.5% per year and industrial-fuel usage is to continue at an established rate of 3% annually. Summation of these three projections yield a saturation curve presented in Figure 8.

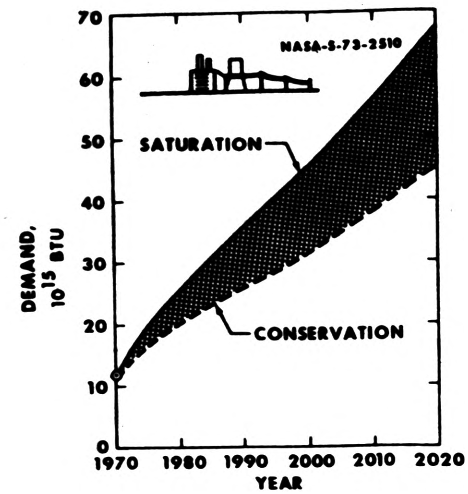

Figure 8.
Electric Power Generation Demand, 1970-2020

Future conservation in the area will be possibly dependent upon conservation in the user areas. More conscious use of electricity by the consumer will definitely cause decreased use in electric generation. The conservation curve of Figure 8 allows that 50% of the savings due to residential and commercial area conservation will be reflected in this area. The industrial-fuel savings of 10% are transferred to a like savings in electric power generation. In 1985, approximately 25% of the generation demand can be conserved by these measures. Energy demands in this area are of course modified by any efficiency changes in generation, but only small overall changes are anticipated. Overall conservation of energy is possible by the use of heat rejected from the generation process for heating; however, this possibility is not reflected in the demand of Figure 8.

Conclusion

A view of the forecast of the United States energy demands indicates substantial increases in the following few years. A realistic view would indicate that significant energy conservation measures will become a necessity. As fuel scarcity becomes a larger factor and a thrust to become energy self-sufficient is implemented, more awareness of energy dependence will force the country into different energy use patterns. It should be recognized that predictions for saturation (Figure 2) and conservation demand (Figure 3) are bounds within which the real use will fall, not expected real values.

As with any forecast, the accuracy can only be assessed with the passage of time, but trends may be noted much earlier. This forecast was made in the summer of 1973 and already several items predicted have began to show in the United States patterns of life.

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